The Human Price
How Environmental Toxins Affect the Human Body

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"Our heedless and destructive acts enter into the vast cycles of the earth and in time return to bring hazard to ourselves"[1]
Rachel Carson, 1963

Introduction

Northwest School of the Arts is a public arts magnet school in Charlotte, North Carolina. It provides a first class, college preparatory education with rigorous academics and a requirement for students to choose a major in the visual or performing arts. This magnet school serves just under 1,000 students in grades 6 – 12 with more than 70% of the population being female. They are talented, bright and eclectic. Most students who attend this school have the ability to balance their academic and art classes with such an ease than can only be indicative of an intense passion for each. Students choose to be at Northwest and must maintain a certain grade point average and class track to remain there. What makes our school so fantastic is that it draws together students of different cultural, racial and socioeconomic backgrounds from all across Mecklenburg County and brings them to a place where common passions are shared, supported and valued.

Rationale

I teach high school life science courses, such as Biology, Advanced Placement Biology and Honors Human Anatomy and Physiology…at an arts school. This is not an easy task. The students crave hands-on, real world lessons and experiences from teachers who think outside of the box. I intend to incorporate this curriculum unit into my Honors Anatomy and Physiology program of study into which I already integrate the arts from a previous Charlotte Teachers Institute seminar. There are about forty students enrolled in this course and it meets every other day for seventy-five minutes for the entire school year with a tutorial being offered every other Thursday for forty minutes.

The course studies the regional and systematic structures and functions of the human body starting at the chemical and cellular levels. Emphasis is placed on histology (the study of tissues) and the major systems of the body. This environmental seminar is very relevant to the intense and rigorous curriculum as I will try to make my students more cognizant of their influence on the world around them and, in turn, the potential negative impact of environmental contaminants on their bodies. Humans handle materials everyday that are considered toxic, but are unaware of their effects on the body.

Toxicology is the biological study of how chemicals adversely affect life; relating the dose and the effects on organisms.

Anatomy and Physiology Course of Study

I divide the course curriculum into units based on the physiological functioning of the body as outlined below. Special emphasis throughout the school year will be on factors that disrupt homeostasis such as certain diseases, disorders and/or environmental toxins.

1. Introduction to Anatomy and Physiology
2. Cytology and Histology
3. Protection, Support and Movement
4. Absorption, Excretion and Transport
5. Integration and Regulation
6. Immunology
7. Reproduction

What are Environmental Toxins?

Environmental toxins are any substances that can cause harm to a biological system. They are in our air, water, food, the houses we live in and the cars we drive, what we use to clean our homes, what we use to clean and moisturize our own bodies, make-up, and the chemical medicines that our medical system provides for us and are a result of our modern and comfortable 21st Century living. Toxins are compounds that are either found in nature or synthetically made and can cause damage inside the human body by altering its physiologically operations. They can enter the human body through the respiratory, digestive, and/or integumentary systems...*breathe, eat, touch*. There are many ways to describe the toxicity level of chemicals which will be explored in great detail during the Toxicology Lab later in the curriculum unit.

This curriculum unit will deal with those toxins we ingest or inhale only, however, most toxins can enter our bodies in multiple ways. "The human body has the ability to cleanse itself of many toxins…each person's threshold is different and is determined by body mass, density, weight, and unique genetic characteristics. Children, people with illnesses, and the elderly often have lower thresholds than the average adolescent or adult."[2] When the accumulated levels of certain toxins exceed the body's natural ability to rid itself of them, the toxins become dangerous.

There are many types of toxins produced both naturally in living cells known as biotoxins (cyanotoxins, mycotoxins and neurotoxins) or man-made synthetically. Toxins can be categorized by the type of damage they cause to organisms. Mutagens are substances that cause molecular and genetic changes in an organism's cells while carcinogens are chemicals that provoke unregulated mitotic activity among cells causing the growth of tumors and cancer. Teratogens, also called embryotoxins, cause birth

defects, abnormalities and developmental impediments. Reproductive toxins, such as lead, can cause sterility and decreased fertility.

This Is Your Brain On…Toxins

The brain commences "its development twenty-five days after the egg and sperm unite, the brain adds the last, refining touches to its frontal lobe about twenty-five years later."[3] There are critical time periods (fetal, infant and childhood) during the development of the brain and other systems of the body where toxins can be more injurious affecting cognition, language, memory and attention. A Duke University Medical Center pharmacology professor, Tom Slotkin, was quoted as relating brain growth and development to playing a complex piano piece. "Certain keys have to be struck at the right intensity at the right pattern. Now, imagine that someone comes along with a chunk of [wood] and presses down a dozen keys" at the same time. Slotkin communicates that different toxins "whack the brain" similarly to how that piece of wood "whacks your piano."[4] The tune is different and sometimes, even worse, the entire song is a disaster.

A New Medical Term

Environmental illness, known also as 20th Century Illness transpires "when you are exposed to toxins or substances in the environment that make you sick. These health hazards may be found where you live, work, or play."[5] Warning signs might be so slight at first that you may just notice nausea, headaches, muscle aches, or perhaps a rash that you could attribute to another common, harmless condition. Scarier yet, environmental illness is very difficult to have a medical professional diagnose once you do figure out that toxins could be causing those general symptoms. Characteristic of environmental illness is an over-sensitivity to many stimuli in the environment such as pollen or mold or certain types of foods. Diseases considered to be environmental illness are associated with our perpetually toxic environment and include asthma, allergies, chronic fatigue syndrome, lupus, fibromyalgia among many others.

Endocrine Disruption

Endocrine disruptors are chemicals that muddle with natural signals that regulate the body's physiology and development. Esteemed professor and environmental health analyst, Dr. Theo Colborn wrote a book called Our Stolen Future which brings awareness to the scientific discoveries around this phenomenon. Dr. Colborn and most endocrinologists refute the common toxicological proverb (the dose makes the poison) surrounding the monotonic-dose response curve which claims that as the quantity of the toxin increases, so does the effect.[6] Research argues that, while dose still does indeed matter, smaller doses of certain toxins can nevertheless cause detrimental harm within the human body. With certain chemicals, "a very low dose makes a higher poison. It is no longer safe to assume that lower doses have lower impacts than higher doses."[7] The

poison is not the dose, but rather the actual exposure in the first place is. The National Institute of Environmental Health Sciences states that,

> A wide range of substances, both natural and man-made, are thought to cause endocrine disruption, including pharmaceuticals, dioxin and dioxin-like compounds, polychlorinated biphenyls, DDT and other pesticides, and plasticizers such as bisphenol A. Endocrine disruptors may be found in many everyday products including plastic bottles, metal food cans, detergents, flame retardants, food, toys, cosmetics, and pesticides. [We support] studies to determine whether exposure to endocrine disruptors may result in human health effects including lowered fertility and an increased incidence of endometriosis and some cancers. Research shows that endocrine disruptors may pose the greatest risk during prenatal and early postnatal development when organ and neural systems are forming.[8]

Why Does It Matter So Much?

Toxins upset all levels of the organization of life from the basic unit of cells, among different types of cells, between organs of the body and even symbiotically between different organisms, including from one species to another. When cell physiology is anarchic, then basic life processes (such as excretion, transport, synthesis, respiration, etc.) are not able to take place. In this unseen microscopic spectrum, diminutive causes spur potent effects. Poisons in our bodies are both excreted and stored while impairing the structures that rid our bodies of them in the first place. "A liver damaged by pesticides is not only incapable of protecting us from poisons, the whole wide range of its activities may be interfered with."[9]

Biomagnification

Biomagnification, or bioaccumulation, is a scientific term used to describe the increasing concentrations of toxins up through a food chain. Top consumers, like humans, reap the greatest risk of ingesting high amounts of toxins. Probably one of the best examples of this phenomenon in history is documented by "the nun of nature."[10] Rachel Carson's Silent Spring , was published in 1962 and was deemed by an Alaskan Senator to have had "substantially altered the course of history"[11] during her testimony before senatorial committee on the dangers of pesticides. Carson wrote about "the most powerful pesticide the world has ever known"[12] which was much later found to be both carcinogenic and mutagenic and banned in the United States in the early 1970s.

DDT was first manufactured in the 1800s but its powerful abilities to kill malaria-transmitting insects and its de-lousing capability were not uncovered until the late 1930s during World War II. Paul Hermann Muller was later awarded the Nobel Prize for these discoveries. It was used on crops years later by civilians and proceeded to remain toxic

in the environment even after dilution by rain water. It entered the bodies of animals through the food they ate and accumulated in their fat tissue. "The book's most haunting and famous chapter, *A Fable for Tomorrow*, depicted a nameless American town where all life – from fish to birds to apple blossoms to human children – had been *silenced* by the insidious effects of DDT."[13]

The Children Are Our Future

Sandra Steingraber quotes that "pound for pound of body weight, children drink more water, eat more food, and breathe more air than adults."[14] She also goes on to inform us that a child's metabolism is so different from that of an adult's, which causes their bodies to detoxify itself and emit those toxins much more slowly. Children are also more inclined to "neurological toxicity"[15] because their blood-brain barrier is more permeable than that of an adult.

Children are more at risk than most adults of being infiltrated by environmental toxins because they are smaller and lower to the debris and germ-stricken ground. They are explorers by nature touching, tasting and breathing in their environments constantly. Children have both lower body mass and metabolic rates and fewer natural detoxifiers.

According to the CDC, "Today at least 4 million households have children living in them that are being exposed to lead. There are approximately half a million U.S. children ages 1-5 with blood lead levels above…the reference level at which CDC recommends public health actions be initiated."[16] Children can suffer brain damage even from very low lead levels. There has been research that supports "inverse relationships between IQ and blood lead levels…[and that there is] no evidence of a safe threshold."[17]

"One in 8 U.S. children is born premature" and this "is the leading cause of death in the first months of life and the leading cause of disability."[18] The rate of babies born before the 37th week of pregnancy has increased 36% since the 1980s. Premature babies are at an increased risk of developing lasting health problems such as breathing and heart issues, diabetes, both vision and hearing loss, learning disabilities, and, autism as well as other very serious disorders. Many things can attribute to premature birth such as certain demographics, infections, cervical irregularities, obesity, stress, lifestyle choices, etc. Research has shown that environmental toxins can cause premature birth as well. Chemicals such as benzene, lead, pesticides, and phthalates have been associated with the reduction in human gestation. These chemicals are described in great detail later in the curriculum unit. Cigarette smoke, which contains toxic compounds, has also been associated with preterm birth. What is the most daunting, however, is that the "relative risks for environmental tobacco tended to be higher than those for direct smoking,"[19] according to studies described by the National Academy of the Sciences.

"One in 11 U.S. children has asthma, the most common chronic disease and a leading cause of school absenteeism."[20] According to Table 1 of J. Grigg's article on environmental toxins using 2002 World Health Organization data, chronic respiratory diseases are the third leading global burden associated with the environment.[21] Toxins such as ozone, gaseous wastes from cars and power plants, phthalates contained in ever-present plastics as well as other forms of air pollution are directly related to asthma. Air quality is directly proportional to the respiratory well-being of children. "In Switzerland, an 11-year decline in airborne particulate matter was followed closely by immediate improvements in children's lung function. Likewise in China, after the government closed a polluting coal-fired power plant in 2004."[22]

"One in 10 U.S. children has a learning disability, and nearly 1 in 10 has attention deficit/hyperactivity disorder."[23] Lead, mercury, arsenic, air pollution, and pesticides are a sampling of the toxins that are linked with these syndromes and will be discussed later in the unit. According to a 1998 article written by Elizbeth Guillette in the Environmental Health Perspectives Journal, preschoolers exposed to higher levels of pesticides scored lower on certain cognitive ability tests and tended to be more aggressive with less social skills than similarly-aged children who were exposed to much less levels of these pesticides.[24] Developmental neurotoxicants are a group of chemicals that damage the fetal and infant brain so much that it causes a hindrance of learning. The Environmental Protection Agency has been cataloging and researching these chemicals and devising a roster which includes, but is not limited to, toxins such as cadmium, benzene, pesticides (including DEET), lead, BPA, mercury and arsenic (all of which are described in further detail later in the curriculum unit).

"One in 10 U.S. white girls and 1 in 5 U.S. black girls begin breast development before the age of eight" which is on average "nearly two years earlier than it did in the early 1960s."[25] The early arrival of puberty in our nation's girls correlates with both premature birth and low birth weight, which, as stated earlier, are linked to many environmental toxins.

Breathe

"Although in humans, pollutants can affect the skin, eyes and other body systems, they affect primarily the respiratory system."[26] Humans are able to breathe via the respiratory system starting with the mouth and/or nose, down the trachea and into lungs. The lungs are made up of bronchioles and tiny air sacs called alveoli. It is through the latter structure where the exchange of oxygen and carbon dioxide waste occurs to and fro the bloodstream.

Oxygen latches on to hemoglobin, a protein on the surface of our red blood cells and roller coasters to every part of our body so the cells there may make the highly energized nucleotide, adenosine tri-phosphate via cellular respiration. Without oxygen, our cells

will be deprived of the energy they need to function normally and strong. "Damage to the lungs from air pollution can inhibit this process and contribute to the occurrence of respiratory diseases such as bronchitis, emphysema, and cancer."[27]

Toxins We Breathe

Asbestos, Benzene, Cadmium, POPs, Lead, Ozone, Radon and Vinyl Chloride

Asbestos is a strong, heat resistant, and highly carcinogenic group of six minerals causing lung cancer, mesothelioma, and the irreversible asbestosis respiratory disease. It has been used for over 4,000 years in construction and later, the automobile industry. The earliest documented health effects date back to the early 1900s. The United States began diverging from use of these fibers in new construction because of their negative consequences on human health, but it can still be found in many buildings because it is deemed too dangerous to remove. Certain studies confirm that "10,000 people are dying of asbestos-related diseases annually" and that "corporate executives knew and concealed the dangers from workers making or handling asbestos-laden building materials, roofing, insulation, brake and clutch linings and hundreds more products."[28]

Benzene is a hydrocarbon released by natural events (volcanoes or forest fires) and from burning fossil fuels such as coal and petroleum. It is "one of the top 20 chemicals in production in the United States"[29] and is used when producing plastics and rubbers, fibers, dyes, pesticides and detergents and is found in cigarette smoke. This sweet-smelling chemical is anything but delightful as it has been classified as both a carcinogen and mutagen. According to the Centers for Disease Control and Prevention, benzene is one of the top produced chemicals in the United States and human exposure to about 20,000 parts per million for 5 minutes or so is fatal. "OSHA currently requires…that workers be provided with and required to wear [respirators] in concentrations exceeding only 1,000 parts per million."[30] Chronic exposure to this unstable, flammable, easily vaporized liquid can cause blood disorders, reproductive and developmental maladies, increased prevalence of leukemia and "neurologic, immunologic, and hematologic"[31] effects.

Cadmium is a naturally-occurring metal emanating from the earth's crust. It comes from smelting, the burning of fossil fuels and wastes, and the production of certain fertilizers. It is used in the making of pigments, batteries, plastics and as a varnish to avert corrosion in steel and iron. It has been graded as a human carcinogen and affects the human body tremendously by afflicting the cardiovascular, digestive, nervous, urinary, respiratory and reproductive systems.

> The main exposure to cadmium, in people, occurs through the consumption of foods and drinking water, the inhalation of cadmium particles from ambient air or cigarette smoke, and the incidental ingestion

> of contaminated dust or soil. Foods (e.g. grains, cereals, leafy vegetables) that have been contaminated through water and crops grown on polluted soil are the highest source of cadmium exposure for the general population. People with low calcium, protein, or iron reserves appear to absorb cadmium more efficiently and may be at increased risk of developing toxicity.[32]

Persistent Organic Pollutants (POPs) are endocrine-disrupting chemicals that are carbon-based, highly toxic and can endure long distances, traveling and amassing globally. Twelve of the most perilous of the POPs have been coined *the dirty dozen* by The Stockholm Convention on Persistent Organic Pollutants and include dioxins, DDT and PCBs which are explained in further detail below.

Dioxin is coined the most toxic of all man-made environmental toxins and can cause developmental problems and cancer. "In the months following the attack [on the World Trade Center], the number of new asthma cases among children younger than five who lived in lower Manhattan jumped"[33] due to the dioxin-containing haze that resulted from the buildings burning. This group of highly evil compounds can be very problematic to the human body as it damages immune cells, causes reproductive and developmental disorders, disrupts endocrine function and can lead to cancer. "Once dioxins have entered the body, they endure a long time because of their chemical stability and their ability to be absorbed by fat tissue, where they are then stored in the body."[34] According to the United States Environmental Protection Agency, it is thought that most human exposure comes from the food we eat, specifically fatty animals (milk, beef, poultry, etc.) due to bioaccumulation. Why should we be worried? "Because dioxins are widely distributed throughout the environment in low concentrations, are persistent and bioaccumulated, most people have detectable levels of dioxins in their tissues. These levels, in the low parts per trillion, have accumulated over a lifetime and will persist for years, even if no additional exposure were to occur. This background exposure is likely to result in an increased risk of cancer and is uncomfortably close to levels that can cause subtle adverse non-cancer effects in animals and humans."[35]

DDT is described later in the Eat section.

Polychlorinated Biphenyls (PCBs) were banned from production in the United States in the late 1970s, yet our exposure to them via touch, breathing, eating, and/or drinking water still occurs since they are so persistent. The Environmental Protection Agency writes that,

> PCBs have been demonstrated to cause a variety of adverse health effects. PCBs have been shown to cause cancer in animals. PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous

> system, endocrine system and other health effects. Studies in humans provide supportive evidence for potential carcinogenic and non-carcinogenic effects of PCBs. The different health effects of PCBs may be interrelated, as alterations in one system may have significant implications for the other systems of the body.[36]

Lead is another naturally-occurring element (50 parts per million to 400 parts per million) that has been overly-emitted in the environment in large quantities through certain human activities (11,000 parts per million). "A 14-month USA TODAY investigation has found that the EPA and state regulators left thousands of families and children in harm's way, doing little to assess the dangers around many of the more than 400 potential lead smelter locations…"[37] Lead, both mutagenic and teratogenic, can also be considered a reproductive toxin. It disturbs practically every human organ system and is very perilous and undecipherable because exposure often occurs with no obvious symptoms. Health concerns include neurological and behavioral disorders, learning disabilities, seizures and death. Children, as mentioned earlier in this curriculum unit, are more susceptible to adverse effects: brain damage, learning disabilities, headaches, hyperactivity, slowed growth, and hearing problems, among others.

Ozone. Bittersweet. It both protects us from the harmful effects of the sun and can poison our bodies. Ozone is an unstable and highly reactive gas found in the upper atmosphere and absorbs ultraviolet radiation. It is essential for our survival. However, ozone can also be found in the troposphere where we live and breathe. It is toxic and corrosive causing permanent lung damage and respiratory infections. Chronic chest pain, coughing and congestion may persist as well as aggravating pre-existing conditions such as asthma. "In 2009, more than half of Americans lived in countries that received failing marks for either ozone or particulate matter."[38]

Radon. Invisible. Ubiquitous. Radioactive. Carcinogenic. This cancer-causing gas occurs naturally through the breakdown of uranium in water and soil. "…the Surgeon General has warned that radon is the second leading cause of lung cancer in the United States today. Only smoking causes more lung cancer deaths."[39]

Vinyl chloride is considered both a mutagen and carcinogen with a low specific heat, evaporating quickly. It is used to make plastics and vinyl commonly seen in the coatings around pipes and wires as well as upholstery and automotive parts. We are exposed to this toxin via the air that we breathe or the water that we drink. Short term effects of vinyl chloride include, but are not limited to, dizziness, drowsiness, headaches, and extreme cheerfulness as well as irritation to the eyes and other organs. Chronic side effects range from liver and kidney damage and vinyl chloride disease to reproductive sterility and cancer.[40]

Eat

Heterotrophic organisms must obtain energy from other sources as they are not able to make their own food like autotrophs. Through digestion, our organs break down the complex organic molecules (carbohydrates, proteins, nucleic acids, lipids) into smaller monomers that can then be absorbed into the bloodstream to be carried to the cells of the body. A very important eukaryotic cell organelle, the mitochondria, will use the glucose obtained from food and the oxygen we breathe to craft another important molecule through the process of cellular respiration. Adenosine triphosphate (ATP) is knonw as the body's currency or molecular money storing the energy necessary for metabolism. Toxins can do great damage to the human body including depletion of ATP reserves or production. They are metabolized by the liver and/or kidneys. After time, these organs can sustain damage which will allow toxins to build up in the blood and be vicious towards the human body.

Toxins We Eat

Ammonia, Arsenic, BPA, DDT, Mercury, Organophosphates, PFCs and Phthalates

Ammonia is produced naturally by different forms of life and can be found in the water, atmosphere and soil. This colorless, corrosive chemical can be artificialy synthesized and is commonly used in agriculture as part of fertilizer and pesticides, but also can be found in may other products such as textiles, cleaning supplies, explosives and our food. Even though plants depend on ammonia as a source of nitrogen, "exposure to extremely high levels of [it] can cause death, coma, blindness, lung damage, collapse, and seizures"[41]

Arsenic is yet another odorless and tasteless chemical that can enter drinking water and food resources naturally, agriculturally or industrially. It is deadly. Short or acute effects include rash-like changes to the skin, abdominal pain, nausea and vomiting, limb numbness and blindness as well as being carcinogenic after long term exposure. "There have been numerous epidemiological studies that have examined the risk of various cancers associated with arsenic ingestion through drinking water…there is overwhelming evidence that consumption of elevated levels of arsenic is causally elated to the development of cancer at several sites."[42] Sandra Steingraber states some very alarming statistics about arsenic in her book Raising Elijah as quoted below.

> Arsenic is a poison. One ounce can kill 250 adults. It's ranked number one on the federal list of the top 275 most hazardous substances found at toxic waste sites. Arsenic is an element which means it can't break down or go away. At levels far below what's needed to kill a rat or a cheating spouse, arsenic causes cancer of the lung, bladder, and skin. It's also linked to kidney, nasal, liver, and prostrate cancers Both the U.S. Environmental Protection Agency and the World Health Organization

> classify arsenic as a known human carcinogen. Low-level arsenic exposure also carries risk for stroke and diabetes.[43]

Bisphenol A, also known as BPA, is a chemical used to harden certain polycarbonate plastics and craft the lining of various containers from which we drink and eat, such as baby bottles. It is a synthetic estrogen that can emulate the effects of important hormones which we know to cause vast changes in the human body. BPA enters the human body by leaking into our food and water supply as it breaks down. "…the CDC has found BPA in the urine of 93% of surveyed Americans over the age of 6. If you don't have BPA in your body, you're not living in the modern world."[44] BPA has been found to disrupt the well-being of the human body by causing heart disease, diabetes and liver issues. There are developmental and hormonal concerns among children as well.

Dichloro-diphenyl-trichloroethane (DDT), one of the dirty dozen POPs mentioned earlier in the Breathe section, is persistant, bioaccumulative, highly toxic and, fortunately for us, banned from use in the United States as of 1972, 10 years after Rachel Carson's Silent Spring was published.[45] It is carcinogenic and has been linked with liver and reproductive and nervous system issues. Historically speaking, DDT was one of the first chemicals to be established as having negative endocrine effects. It is described in more detail along with Rachel Carson above within the Biomagnification section earlier in this curriculum unit.

Mercury. "From the earth to the air to the water to the dinner table. And so into blood and neurons."[46] Methylmercury (CH_3Hg) is the most toxic form of this element. Mercury is released primarily through the combustion of coal and the incineration of medical wastes as well as mining. Atmospheric mercury can indeed occur naturally as well through volcanoes and geological deposits. "Once in the atmosphere, mercury is widely disseminated and can circulate for years, accounting for its wide-spread distribution."[47] Vaporized mercury can fall back to earth's surface in precipitation where bacteria *methylate* it into the venomous "brain poison"[48] methylmercury. It bioaccumulates through food webs as one organism after another ingests other contaminated organisms. The most common source of human contact is through the fish we eat. Methylmercury is most noxious to nervous system cells found in the brain and spinal cord, especially detrimental to developing embryos or fetuses. Exposure is linked to learning disabilities, attention and memory issues, balance, coordination, problems with the senses (such as blindness or deafness) and cerebral palsy "In 2003, the Centers for Disease Control and Prevention quantified the problem: One of every twelve U.S. women of reproductive age has blood mercury levels above that known to be safe."[49]

Organophosphates, more commonly thought of as pesticides, are chemicals created with the sole purpose to poison are include the most toxic compounds used in agriculture. "We have seen that they now contaminate soil, water, and food, that they have the power to make our streams fishless and our gardens and woodlands silent and birdless."[50] They

kill bugs and while doing so, cause unwanted side effects in animals, such as inhibiting and disrupting the activity of acetylcholine which is an important tool in neural signaling and communication. The less messaging ability between nerves one has, the less cognition or learning occurring. "Children with above-average levels of pesticides in their urine were twice as likely to have a diagnosis of ADHD."[51] Organophosphates were used in the early 1900s to treat muscle and immune conditions and during World War II, certain organophosphates were used as a neurotoxic war weapon by the Germans. Symptoms of the Gulf War Syndrome are also believed to be caused by the use of these chemicals.[52] The Centers for Disease Control and Prevention reports that exposure of organophosphates to lab rats increase their risk of developing certain types of cancers.

Perflurochemicals (PFCs) are a family of synthetic chemicals characteristically slippery, heat-stable, made up of large chains of carbon atoms powerfully attached to fluorine atoms and absolutely not biologically inert like once thought. Their stability makes them exceptionally and dangerously resistant to breaking down. These chemicals are found in an array of household products for various reasons: preventing food from sticking to cookware, waterproofing and deterring stains from settling into fabrics and rugs. Airplanes, cosmetics, cleaners, fast-food and microwave popcorn wrappings, oh my! "As more studies pour in, PFCs seem destined to supplant DDT, PCBs, dioxin and other chemicals as the most notorious, global chemical contaminants ever produced…the most pervasive and toxic members of the PFC family never degrade in the environment."[53] They have correlation to liver and immune issues, high cholesterol, abnormal hormone levels and small birth weight in newborns.

Phthalates are chemicals that have the ability to "dissolve fragrances, thicken lotions, and add flexibility to PVC, vinyl, and some intravenous tubes in hospitals. The dashboards of most cars are loaded with phthalates [contributing to that new car smell], and so is some plastic food wrap."[54] We are exposed to phthalates via breathing, eating, and absorption through the skin. This toxic substance is easily discharged into our surroundings as the products that contain them age because of its weak chemical attachment within the product. Phthalates have been linked to having adverse effects on reproduction and development as well as cancer.

Activities

Toxin Montage

In collaborative groups of two, students will be assigned a particular toxin to research and present as a culminating task in the last term of the school year. Students will be required to describe the chemical molecularly and physically, its sources (both natural and synthetic), use and effects on the human body as well as a detailed diagram of how the toxin enters our atmosphere or food/water supply making life susceptible to its dangers. Part of the research will also entail determining the toxicity rating by using one of the

common toxicity dosages which will be explored during the school year (TDLO or LD50 or LC50). Appendix A contains the rubric for this research project.

Magazine Cover

An artistic and/or technology-based piece will be included in this curriculum unit. Students must create a science journal or magazine cover with news about their assigned toxin, its negative effects and ways to prevent exposure as the issue's highlighted story. Appendix B contains the rubric for this project.

Inquiry Investigations Learning About the Effects of Smoking

Using a laboratory kit from Frey Scientific (item #1287207),[55] students will observe the effect of smoke inhalation on simulated lungs, understand how toxins accumulate in the lungs during smoking, and demonstrate the amount of trapped smoke residue in a normal breath. This lesson allows students to make observations and think analytically while exploring the respiratory system, pollutants and the consequence of smoking. Some important vocabulary terms to know prior to starting this activity are nicotine, smoke, alveoli and tar and students should have a working knowledge of how the respiratory system functions to bring oxygen to the blood and expel carbon dioxide. This activity requires the use of syringe pumps to pull measured amounts of cigarette smoke through a filter on a model of a smoking person. Observations can be made of the accumulation of smoke and tar on filter paper discs. Students will be required to read about the dangers of smoking and of second hand smoke as well.

Anti-Smoking Advertisement

After investigating how the toxins in cigarettes can negatively affect the human body, students will be required to create an anti-smoking advertisement. Students may choose to exhibit their products in any artistic way they wish. The rubric for this project can be found in Appendix C.

Effects of Toxic Chemicals on Cells

Using a laboratory kit from Frey Scientific (item #20-3473),[56] students will evaluate the various types and levels of abnormalities which may arise in cells following exposure to toxins. Students will harvest mouse cells in the presence of both low and high levels of a particular toxin, then stain and mount them, microscopically examining the toxic effects on the anatomy of the cells. Comparisons can be made of these abnormal cells with those of untreated cells. A presentation called "Toxicology and Toxicity Testing" is included in this lab kit to introduce the students to the concept and importance of biomedical research and environmental and health sciences.

Toxicology Lab

This laboratory investigation was adapted from an Advanced Placement Environmental Science activity called Toxic Tea.[57] The modified student sheet and instructions can be found in Appendix D. Students will have a more enhanced comprehension of the notion of toxicity by accomplishing this lesson. The class will complete the pre-lab questions, calculations and research the block before the lab begins (preferably in a computer lab) so that we may have time to review it, answer any questions and sort out any confusion.

Brine Shrimp Article

To get students geared up for this activity, I will assign them to read for homework an article from the Journal of Chemical Education about brine shrimp and toxicity[58] and instruct them to complete an article analysis sheet (see Appendix D).

Background Information

LD(subscript)50 is a term used to describe acute ingestion toxicity. LD means lethal dose or deadly amount while the subscript means the dose was acutely deadly to 50% of the animals tested. These values are expressed in milligrams of the substance per kilogram of body weight (mg/kg = parts per million) and quantified from zero up so the lower the LD50 value, the more toxic the substance. Species react differently to various chemicals so LD50 values on mice or brine shrimp for example cannot be solely used to determine the dose that would be deadly to humans, but the value is constructive in predicting the plausible toxicity in humans.

Make Your Own Toxicology Case Study

While students are researching their Toxin Montage (as described above and in Appendix A), they will also be required to write a case study which will be used as part of a whole class assessment. This lesson is adapted from the National Institute of Environmental Health Sciences[59] and addresses an array of subjects such as environmental science, health and literacy incorporating many 21st Century skills such as communication, critical thinking, research and comprehension. The NIEHS's website contains a lesson on writing an arsenic case study. Students will work in collaborative groups of two to research and write a two to three-page, double-spaced case study about a fictitious person suffering from toxicity including a map of the area in which they live, work or play and some additional images. As I evaluate the work, I will make certain students have factual details about exposure to their assigned toxin for each of the required subheadings and that their outside sources are referenced properly. Teachers should use the NIEHS lesson on arsenic as a reference if this is the first time they are completing a case study in their classroom. Appendix E contains my rubric.

Disease Diary

Every student at Northwest School of the Arts that enrolls in the Anatomy and Physiology course must complete a culminating project that fuses science and art. They must choose six diseases (one of which is a cancer) with which they have a personal affiliation or an interest in studying further and compile a journal of specific facts regarding each disease. They have the first three quarters of the year to work on it (some class time, but mostly on their own) and a detailed list of requirements they must follow as outlined in Appendix F. The art component consists of finding a piece of art that personally represents each disease with an explanation of why and how it represents that disease in their eyes with an inclusion of the artwork. This year, it will be necessary for students to integrate one disease that could be caused by environmental poisons within this diary as well.

Appendix A – Toxin Montage

You will work in groups of two researching an assigned toxin. You will present your findings to the class with some sort of visual (computer presentation, poster, etc.). You will be graded based on presentation skills and research accuracy.

List of toxins: Ammonia, Arsenic, Asbestos, Benzene, BPA, Cadmium, Dioxin, DDT, Lead, Mercury, Organophosphates (DEET), Ozone, PCBs, PFCs, Phthalates, Lead, Radon, Vinyl Chloride

Required information:

- Description (color, taste, physical state of matter, chemical structure, etc.)
- Sources (both natural and synthetic)
- Use
- Acute effects on the human body
- Chronic effects on the human body
- Management and treatment
- Government policy/United States standards
- United States statistics
- Detailed diagram of how the toxin enters our atmosphere or food/water supply
- The toxicity rating by using one of the common toxicity dosages
- Information resources
- Literature cited

Appendix B – Magazine Cover

Independently, create a magazine cover that is about your assigned toxin. Choose a reputable science journal or magazine to mimic such as National Geographic, Popular Science, Discover, etc. Be sure to follow all the requirements listed below. Be creative and make the finished product look as professional as possible. The Young Supernavage Research Scientist Award (YSRS) will be bestowed to the top three research artists. A relevant picture must be included as the feature "star" of the magazine cover.

- Professional and neat layout
- Appropriate magazine title
- At least 6 "article teasers" about your toxin (from your research)
- Large, feature picture as central attribute of this magazine issue
- Another small picture located in a box relevant to the toxin (perhaps a scientist who studies the effects of this toxin, etc.)
- Issue date and price
- Grammar/spelling

Appendix C – Your Butt Stinks!

> Almost 6 million people die from tobacco use each year, both from direct tobacco use and second-hand smoke. By 2020, this number will increase to 7.5 million, accounting for 10% of all deaths. Smoking is estimated to cause about 71% of lung cancer, 42% of chronic respiratory disease and nearly 10% of cardiovascular disease.[60]

You will develop an advertisement to dissuade the public from smoking and to promote healthier living. You will need to develop a unique logo and slogan and may choose from an array of artistic ideas. You may use technologies to create your advertisement such as computers, Ipads, video cameras, etc. Creations include, but are not limited to, billboards (drawn to scale on poster paper), bumper stickers, t-shirts, television commercials (no more than a minute), song or dance. All students must work individually on this project. It counts as a test grade.

Your advertisement should include:

- Creative and colorful visuals
- Unique slogan and logo
- A clear and effective message about how smoking negatively affects the human body
- Professional product and visual appeal
- Names of at least two toxins found in cigarettes

Appendix D – Toxicology Lab

Objectives

After this lab, you should be able to

- explain the concept of toxicity and LC50
- understand the significance of LC50
- understand how LC50 is calculated
- identify sources of environmental toxins in nature.

Article Analysis

Title of Article:
Source and Author of Article:
Main Idea of Article:
Vocabulary: LD50, LE50, LC50, bioassay, brine shrimp, dose-response curve
Relationship to Anatomy and Physiology:

Laboratory Materials

Brine Shrimp, Brine, Herbal Tea Bags, 1 milliliter pipettes, 24 test tubes per group, Test tube rack, Marker

Pre-Lab Questions (done the class before the experiment in a computer lab if possible and reviewed together)

1. Determine how many total grams of each substance in the chart below would be required to kill 50% of a population of 100 clones of yourself. Use your own mass in kilograms. Watch your units and show your work for each conversion to LD50 per person below the table. Remember, not everyone in the class weighs the same so your answers will be slightly different.

Substance	**Common Uses/Sources of Substance***	**LD50 for MOUSE**	**LD50 for YOU**
Benzaldehyde (Cherry flavor)		4.8 mg/kg	
Tetrahydrocannabinol (THC)		110 mg/kg	
Malic acid (sour candy)		1.6 g/kg	
Botulinum toxin (bacteria)		3 x 10-8 mg/kg	
Nicotine		190 mg/kg	

(via mouth)			
Caffeine (Mountain Dew)		0.13 g/kg	
Sodium Fluoride		52 mg/kg	
Tetrodotoxin		334 x 10-6 g/kg	
Gamma Hydroxybutyrate		2.0 g/kg	

* For homework, research the uses of each substance and fill in the chart below. http://www.osha.gov/dts/chemicalsampling/toc/toc_chemsamp.html

Show your work below:

2. A Material Data Safety Sheet is literature on specific chemicals explaining the chemical's properties (physical and chemical), how hazardous the chemical can be, emergency procedures and safe disposal, etc. Find the MSDS sheet for nicotine online and use Sections 4 and 5 to define how nicotine is hazardous and what precautions should be taken when exposed to nicotine in the lab.

3. Find a Material Safety Data Sheet (MSDS) for an ingredient in some household substance you have (e.g. toothpaste, shampoo, mouthwash, junk food additives, etc.) and give its LD50 for the oral route for a person in grams per person. Assume the LD50 of a rat or mouse will be the same as a human. Do not use any of the substances already listed in the table above.

Data Collection

Concentration	**Number Dead**	**Percent Mortality**
Students will need multiple rows**		

**Label the first column with the following names three times each: 10 times, 7.5 times, 5 times, 2.5 times, 1 times, .5 times, .1 times, and pure water.

Procedure

Choose a toxin (tea) and record the type/brand here:

*Preparing the Tea Extract****

A cup of tea contains 200 milliliters of water per teabag, so that would be considered a 1.0x dosage. You will prepare a 10x dosage by using 4 teabags in 80 ml of brine.

Place four bags onto the bottom of a 100 milliliter beaker. Place 80 milliliters of hot brine into the beaker and let it steep for 15 minutes, mixing it gently every 5 minutes. Squeeze each teabag between two spoons several times.

***As the tea is steeping, prepare your Brine Shrimp (see below).

Making the Serial Dilution

Add two milliliters of your 10x stock solution to 18 milliliters of brine. The resulting 20 milliliters of solution will be 1x.

Add two milliliters of your 1x stock solution to 18 milliliters of brine. The resulting 20 milliliters of solution will be 0.1x.

****The Brine Shrimp*

This small crustacean is normally found in salty water and is a very vigorous little organism. It is able to tolerate high salt concentrations. As the tea is steeping, prepare 24 test tubes with 10 Brine Shrimp in each with a spoon or pipette. Leave the brine shrimp in as little water as possible during transfer to minimize the dilution error.

The Test Tubes

You will make three test tubes of each of the following solutions: 10x, 7.5x, 5x, 2.5x, 1x, .5x, .1x as well as a control of 0x. Unless you are using the stock solution (10x, 1x or .1 x) directly on the shrimp, you must make each solution in a small beaker and stir it before adding the solution to the shrimp.

1. Place five milliliters of the 10x stock solution into a vial containing ten shrimp. Label the text tube 10x. Repeat twice, resulting in 3 test tubes of 10x.

2. To make a 7.5x solution, place 3.75 milliliters of the 10x stock solution and 1.25 milliliters of brine into a test tube containing ten shrimp. Label the test tube 7.5x. Repeat twice.

3. To make a 5x solution, place 2.5 milliliters of stock solution and 2.5 milliliters of brine into a vial containing ten shrimp. Label the test tube 5x. Repeat twice .

4. Calculate how you will make a 2.5 x solution? Check with your teacher and complete the step.

Teacher Initials:

5. Place five milliliters of the 1x stock solution into a test tube containing ten shrimp. Label the test tube 1x. Repeat twice.

6. To make a 0.5x solution, place 2.5 milliliters of the 1x stock solution and 2.5 milliliters of brine into a vial containing ten shrimp. Label the test tube .5x. Repeat twice.

7. Place five milliliters of the 0.1x stock solution into a test tube containing ten shrimp. Label the test tube 0.1x. Repeat twice.

8. Prepare a control of ten shrimp in brine. Repeat twice.

9. After 24 hours, count the surviving brine shrimp. Calculate the percentage of death and record in your data table.

Analyzing the Data

The Graph

Create a scatter graph of concentration on the x-axis vs. mortality on the y-axis. Mark the LC50 on your printed graph. You may use a computer program such as Microsoft Excel to create your graph.

The Questions

1. What is the LC50 for your tea on brine shrimp?
2. Based on your data in this lab what is the safe concentration for brine shrimp (Lowest Observable Effect Concentration or LOEC)?
3. If you pursue this investigation further in order to publish your results in a scientific journal, what would you do to improve upon this lab?
4. Brine Shrimp have a higher tolerance for many pollutants than does another crustacean, the Daphnia (the water flea). Indicator species are used to study the overall health of an ecosystem. If you were to study an ecosystem would you use the Brine Shrimp or the Daphnia as indicator species? Explain your reasoning.
5. In this investigation, you are actually determining the LC50 (Lethal Concentration) rather than the LD50 (Lethal Dose). What is the difference, and why is the difference important?

Appendix E – Make Your Own Toxicology Case Study

Create a well-researched profile of a fictitious person suffering from poisoning (acute or chronic) of your assigned toxin. Be creative and tell an accurate story being certain your details and facts are credible. Use proper grammar and type two to three pages in Times New Roman, 12-point font, double-spaced. Your patient (adult or child, male or female) may be from anywhere in the world that suffers from exposure of the toxin. This counts as a test grade.

Include the following criteria in your case study:

- Patient's Name and Age
- Chief Complaint(s)
- Medical History
- Physical Exam Observations
- Medical Tests Complete and Results
- Environmental Findings
- Recommended Treatment
- Detailed and Labeled Map of Area (work, live, play)

Appendix F – Disease Diary

Choose six diseases with which you have a personal affiliation or an interest in studying further. You will be required to research a collection of facts in great detail regarding each disease you have picked. You should organize your information in a professional and creative way. Paragraphs of information and copy-and-pasted notes should NOT be part of your journals. Be sure to use proper grammar and punctuation and put the information in your own words. Include a section at the bottom of each diary entry to cite where you found the facts and figures, etc. Your data and research must be accurate! Your finished product must be typed and is due at the end of the third quarter. The date will be announced later in the year. Class time will be allotted to work in the Library Media Center occasionally throughout the year, but students should work on this project throughout the year on their own time.

Diary Entry Requirements:

- One disease must be a type of cancer.
- One disease must be the cause of a chronic effect of an environmental toxin.
- Each disease must be of a different organ system (although it is fine if the diseases overlap in different systems).
- Disease Name – centered and bold
- General Overview – be sure you list the human organ systems it affects and include the etiology (how the disease is acquired)

- Signs and symptoms
- Treatment options/cure
- Prevention or ways to lower the risk factors
- Prognosis/Research being done
- Famous people who have suffered or are currently suffering from this disease
- Relevant Statistics
- Art Component: You will need to find or create art that personally represents each disease with an explanation of why and how it represents the disease in your eyes. Include both the artwork and this explanation in your diary.

Appendix F – Teacher and Student Resources

50 Most Creative Anti-Smoking Advertisements
http://10steps.sg/inspirations/artworks/50-most-creative-anti-smoking-advertisements/

Agency for Toxic Substances and Disease Registry
http://www.atsdr.cdc.gov/

Arsenic Case Study
http://www.niehs.nih.gov/health/assets/docs_a_e/ehp_student_edition_lesson_arsenic_an_element_of_suffering.pdf

Chemicals on the EPA's Roster
http://investigativereportingworkshop.org/investigations/toxic-influence/story/chemicals-on-list/

Environmental Health News
http://www.environmentalhealthnews.org/

Environmental Working Group's Chemical Index
http://www.ewg.org/chemindex

National Library of Medicine Hazardous Substances Data Bank
http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB

National Library of Medicine's ToxTown
http://toxtown.nlm.nih.gov/index.php

Time's Environmental Toxin Archive
http://www.time.com/time/specials/packages/0,28757,1976909,00.html

United States Environmental Protection Agency

http://www.epa.gov/

United States POP Watch: The Dirty Dozen
http://www.uspopswatch.org/global/dirty-dozen.htm

What is LD50 and LC50?
http://www.ccohs.ca/oshanswers/chemicals/ld50.html

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